# AMERICAN RAILROAD JOURNAL,
## AND ADVOCATE OF INTERNAL IMPROVEMENTS.

## AMERICAN RAILROAD JOURNAL.

### NEW-YORK, JUNE 25, 1836.

#### STEAM-BOAT NOVELTY.

We have frequently desired to refer more particularly to the operations and experiments of Dr. Nott, than we have felt at liberty to do; inasmuch as we were aware of his desire to avoid newspaper or periodical notoriety; we cannot, however, refrain from embracing the present opportunity of expressing our admiration of the perseverance with which he has pursued his experiments on the use of anthracite coal for steam navigation.

We conceive that Dr. N., in perfecting his machinery, has laid society under the greatest obligations--we need only point to the destruction of our forests--where is our wood to come from if each of our immense boats consumes 30 to 40 cords per day? We have not been in the habit of considering our forests as other than inexhaustible, but such is the state of things no longer, and we hear complaints from every quarter. Indeed no one could witness the enthusiasm with which the success of the experiment was hailed in every place and at Albany in particular, without being convinced that the substitution of coal for wood has been made *not one day too soon.*

We had the pleasure of being of the party to Albany last week in this beautiful boat. Seldom has it fallen to our lot to make a more pleasant trip. The perfect feeling of security combined with the consciousness of the boat's great speed produced in us a sensation of pleasure as agreeable as unusual.

The Novelty is 252 feet long—certainly our longest boat and we think the largest in the world—her engines are horizontal—two large ones, and a small one for blowing the fire, pumping, &c.

The grates are on the principle of Dr. Nott's improvements in the use of Anthracite coal—the boilers are tubular.

The economy of the various parts of the machinery is beautiful but we shall not attempt a description in detail. It is sufficient to say that the operation of the boat is most successful. We have never made a passage during which we have less felt the vibration of the machinery, and notwithstanding the boat's great length the motion at her extreme ends as well as beside her machinery was far less than usual.

The great object of the proprietors has been the saving in fuel, and that has been attained most ingeniously. The cost of fuel is less than one half of that in the wood boats. Nineteen to twenty tons will probably be used in a trip.

On Thursday last during the passage the boat had to contend with ebb tide—a freshet in the river—strong N. E. wind. Her time was as follows:

|  | h. | m. |
|---|---|---|
| Left New-York | 6 | 27 |
| Passed Teller's Point | 9 | 27 |
| Verplanks's Point | 9 | 57 |
| Caldwell's | 10 | 5 |
| West Point | 10 | 40 |
| Newburgh | 11 | 28 |
| Poughkeepsie | 12 | 32 |
| Hyde Park | 1 | 4 |
| Rhinebeck | 1 | 52 |
| Barrytown | 2 | 52 |
| Bristol | 2 | 57 |
| Catskill | 3 | 43 |
| Hudson | 3 | 57 |
| Coxsackie | 4 | 29 |
| Baltimore | 5 | 5 |
| Coeyman's | 5 | 17 |
| Arrived at Albany | 6 | 37 |

Making the whole passage in 12 hours 10 minutes.

An accident before leaving the dock, injured the iron attached to the rudder and prevented the more rapid alteration of the course of the boat, particularly in following the shore to avoid the tide and catch the eddy. This had considerable influence in coming down the river.

On the return of the boat on Saturday two flood tides were encountered, the one at Baltimore, the other at the Highlands. The times were as follows:—

|  | h. | m. |  |  |
|---|---|---|---|---|
| Left Albany | 8 | 5 |  |  |
| Passed Coeymans | 9 | 6 |  |  |
| Baltimore | 9 | 15 |  |  |
| Cocksackie | 9 | 43 |  |  |
| Hudson | 10 | 15 |  |  |
| Catskill | 10 | 54 |  |  |
| Tivoli | 11 | 21 |  |  |
| Barrytown | 11 | 38 |  |  |
| Rhinebeck | 11 | 58 |  |  |
| Hyde Park | 12 | 36 |  |  |
| Poughkeepsie | 12 | 58 | 2½ | lost |
| Passed the Erie, coming up | 1 | 2 |  |  |
| Newburgh | 1 | 52 |  |  |
| West Point | 2 | 20 |  |  |
| Caldwell | 2 | 54 |  |  |
| Yonkers | 4 | 35 |  |  |
| Arrived at New-York | 5 | 53 |  |  |

Deducting the landing, making the passage in 9 hours 45 minutes.

Below Poughkeepsie, came in sight of the morning boat, the Champlain, she having left Albany at 7 o'clock, making her usual landings.

She came into the wharf about ¼ a mile, or ¾, ahead of the Novelty. From Newburgh down to New York, dense volumes of smoke issued from all four pipes of the Champlain, proving the enormous consumption of fuel; while we feel it our duty to say, that no strain whatever was upon the Novelty—she going at such a rate as is entirely practicable every day.

No coal was put into the furnaces for the last thirty miles on either trip; and while the other boat was smoking furiously, the firemen of the Novelty were upon the front deck cooling themselves, and rejoicing in their light work. They, at least prefer coal to wood.

Speed is certainly desirable, and we were agreeably surprised to find this boat move with such rapidity on a first voyage, when every thing must be new to the hands, having never before used such fuel; whereas,

in the ordinary engines, the practice of many years is extended to their benefit. But safety is the all-important object, and never could we desire a more safe mode of conveyance. The terror of a rupture of the boiler is here unknown. Should a boiler burst, it would only result in the collapse of a small tube, and put out the fire.

We can add nothing more than to inform our readers, that this boat is commanded by Capt. Seymour, assisted by Capt. Lewis, so long and creditably known upon the North River; we can answer for the treatment his passengers will receive.

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### RAILROAD CONVENTION.

The period for the meeting of the Great Southern Railroad *Convention* at *Knoxville*, Tennessee, is at hand. The object of that meeting, viz., the *connection of the southern seaboard at Charleston, S. C., with the Ohio at Cincinnati, and probably at Louisville, Ky.*, is worthy of the attention of all the friends of Internal Improvement; and it will, we are sure, be ably advocated by those selected to attend the convention.

It was our *intention* to be at Knoxville during the Convention, but other engagements will prevent; we must therefore rely upon some friend to furnish the proceedings at an early day for the Journal.

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### RAILWAY IN ILLINOIS.

We give in this number of the Journal a map of Illinois with the principal rivers, towns, and chartered railroads delineated thereon. The object of this map is to give to the people of this eastern section of the country, a better idea of the State of Illinois, and its progressing, and contemplated improvements, than they now possess—and, although it is not as full as we could desire, yet, it will be found of much use to those who contemplate a visit, or removal to that fertile region. We have not the necessary documents before us, to go into a full, or general description of the various improvements laid down on this map, yet we cannot permit the opportunity to pass without calling attention to one or two of them, and we will commence by referring to No. 1, the National road which is now in progress as far as Vandalia. An Engineer is engaged in surveying the route from thence to Jefferson city, crossing the Mississippi river at Alton; there is no doubt but that it will be continued, at least to that point.

2, and 3. The road from Alton, on the Mississippi, to Springfield, in Sagamonn county. Alton is a very flourishing town—city we shall have soon to say—situated about 2½ miles above the mouth of the Missouri, and eighteen miles below the mouth of the Illinois rivers. Alton is said to have the best steam-boat landing on the east bank of the Mississippi, having a natural wharf of rock, of a convenient height and level surface. The Penitentiary is located there, and there are many who think it will yet become the capitol of the State. There is an abundance of good timber, bituminous coal, limestone, free stone and hydraulic cement in its immediate vicinity. The town is laid out upon a liberal scale, having *five* squares reserved for public purposes, and streets of 150, 100, 80 and 60 feet in width according to their location. It has already several large wholesale stores and steam mills—and must eventually beyond all question become a very important place.

The railroad from Alton to Springfield has been surveyed, the company organized and measures adopted for an early and efficient prosecution of the work. It will be connected with other roads, particularly that leading from Springfield to Danville through Decatur—and another from Springfield through Jacksonville to Meredosia, on the Illinois, and Quincy on the Mississippi rivers, both of which are chartered and the stock of the latter we understand is taken.

4. Rail Road from Danville to Springfield by Decatur, 110 miles,—already chartered. This road, when completed, will connect Alton with Danville.

5. Rail Road from Springfield to Quincy by Jacksonville and Meredosia, 90 miles. Chartered. Will open a rail road communication between Alton and Quincy.

6. Rail Road from Alton to Galena via Carrolton, Jacksonville, Beardstown, &c. Chartered. Distance, 350 miles.

7. Rail Road from Grafton to Springfield via Carrolton and Waverly. Connects with the Alton and Galena road at Carrolton.

8. Rail Road from a point on the Illinois river on the Jacksonville and Waverly, to intersect the Alton and Springfield Rail Road at Auburn.

9. Rail Road from Alton to Mount Carmel on the Wabash. Chartered. 150 miles.

10. Rail Road from Alton to Shawneetown. Chartered. Distance, 150 miles.

11. Rail Road from Galena to Ottawa (or the termination of the canal,) and thence to the mouth of the Ohio. Chartered. Intersects the Alton and Shawneetown Rail Road, and connects Alton with the mouth of the Ohio.

12. Canal from Chicago to Ottawa, 95 miles. Commenced this year.

This canal is to be 36 feet wide at bottom, 60 at its surface and 6 feet deep—It *should be eighty* feet wide and *eight* feet deep, with Locks of sufficient dimensions to admit the passage of *Steam Boats*; and it will have to be enlarged to those dimensions *within ten years*.

13. Rail Road from Danville to La Fayette, proposed by Indiana. At La Fayette the Wabash and Maumee terminates. From La Fayette Rail Roads are projected by Indiana to Evansville, and through Indianapolis to New Albany, Madison, and Lawrenceburg on the Ohio River, and from Lawrenceburg a Rail Road is to be made to Cincinnati, connecting Alton with all these places.

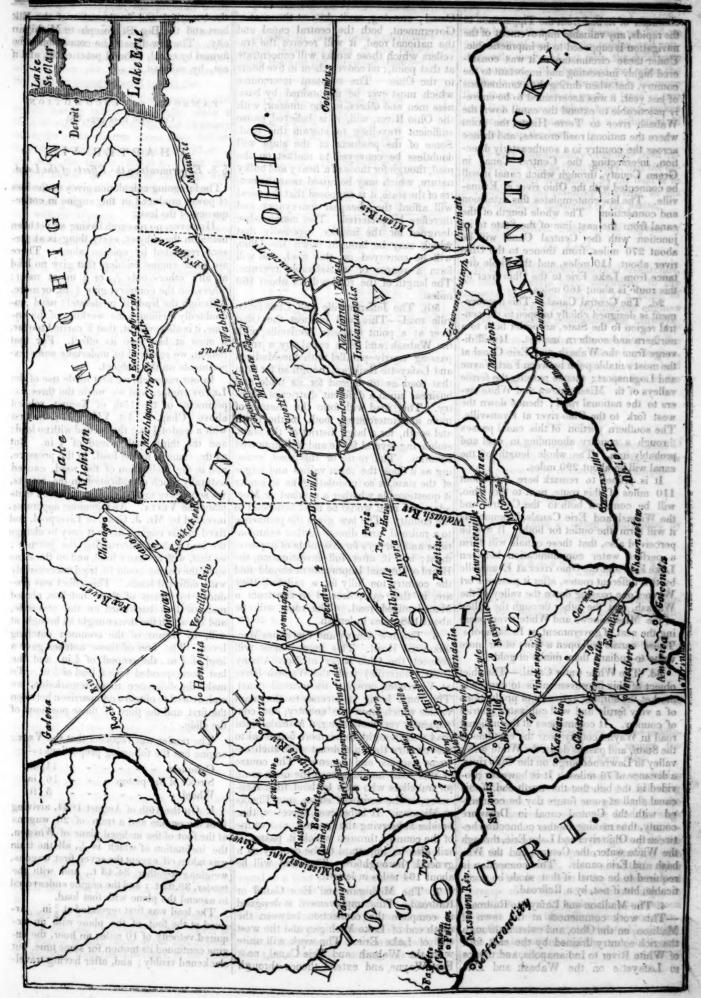The preceding brief description of the several improvements which were authorized, and undertaken on the part of the State, by the law of last Session of the Legislature, and which are therefore properly included in what is termed the state system of internal improvement, will be found highly interesting to those who are in any way connected with the prosperity of Indiana. It is proper to remark, however, that in addition to these, a railroad from Indianapolis to Lawrenceburg has been commenced, and is now in progress by an enterprising company under a charter from the State; and numerous others will doubtless be undertaken by the inhabitants, by which the state works will be intersected, and connected in various other places, thereby giving to every part of the State those facilities which are essential to the proper developement of its immense resources; and at the same time give to the soil of an infant, and but recently, *wilderness* state, the value and advantages of an old and thickly settled country.

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### INDIANA.—INTERNAL IMPROVEMENTS, &C.

We have been furnished with documents which enable us to lay before our readers the following facts, referring to the map. They give the reader a better idea of those works than we have before been able to furnish.

The system of public works authorized by the act of the last Legislature, authorising the loan of ten millions of dollars, embraces the following described routes, which will be better understood by an examination of the map of the State, of which a copy may be seen at our office, or of the accompanying map of Illinois and Indiana together.

1st. The Wabash and Erie Canal.—This improvement is decidedly the most important one in the State. It commences at the head of steamboat navigation, on the Maume river, which empties into Lake Erie at its extreme western point, and follows up the valley of that river to Fort Wayne, and down the Wabash to La Fayette, thence to Terre Haut, and Evansville, on the Ohio river, and may indeed be called the basis or main trunk of the system, inasmuch as all the other lines are designed to connect with it, and will find their outlet to a northern market through this channel. Besides affording an outlet to market for half the State of Indiana, it will also form, when extended to the Ohio, one of the principal channels of trade between Lake Erie and the western and south western states. Additional importance is given to the work from the fact that a Railroad is about to be commenced at Alton, Illinois, near the mouth of the Missouri, which is designed to intersect the Wabash and Erie Canal at Covington, or La Fayette; passing across the entire state of Illinois, and thus open the most direct route from New York to St. Louis, and the whole south western country. This canal was authorized some years ago as far west as the mouth of the Tippacanoe, the point to which steamboats can ascend during high water; the work has been for some time in progress, and within the present season 65 miles will be navigable. But the navigation of the Wabash river, though highly important to the country, is believed to be entirely inadequate to the increasing commerce of this route, especially if the transit trade be taken into the account. The improvement of the river for steamboat navigation has been suggested, but owing to the very sandy

Map labels (clockwise): Lake St. Clair; Lake Erie; Detroit; MICHIGAN; Maumee; Fort Wayne; OHIO; Columbus; Cincinnati; Miami River; National Road; Indianapolis; KENTUCKY; Lawrenceburgh; Madison; Louisville; Wabash; White River; Vincennes; New Albany; Shawneetown; Golconda; America; Trinity; Jeffersonville; INDIANA; Lafayette; Michigan City; St. Joseph; Edwardsburgh; Chicago; Kankakee R.; Canal; Fox River; Ottoway; Vermillion Riv.; ILLINOIS; Rock Riv.; Galena Riv.; Hennepin; Peoria; Terre Haute; Paris; Palestine; Aurora; Decatur; Shelbyville; Bloomington; Springfield; Vandalia; Carlyle; Maysville; Pinckneyville; Carmi; Equality; Jonesboro; Chester; Kaskaskia; Belleville; Lebanon; Edwardsville; St. Louis; MISSOURI; Missouri Riv.; Jefferson City; Mississippi Riv.; Illinois River; Lewiston; Rushville; Beardstown; Quincy; Troy; Columbia; Fulton; Jacksonville; Carrollton; Hillsboro; Greenville; Carlinville; Sterling field; Wabash River

character of its bed from the Tippacanoe to the rapids, any valuable improvement of the navigation is supposed to be impracticable. Under these circumstances it was considered highly interesting and important to the country, that when during the examinations of last year, it was ascertained to be entirely practicable to extend the canal down the Wabash river to Terre Haute, the point where the national road crosses, and thence across the country in a southeasterly direction, intersecting the Central Canal in Green County, through which canal it will be connected with the Ohio river at Evansville. The law contemplates this extension and connection. The whole length of the canal from the east line of the State to its junction with the Central Canal will be about 270 miles, from thence to the Ohio river about 110 miles, and the whole distance from Lake Erie to the Ohio river by this route is about 460 miles.

2d. The Central Canal.—This improvement is designed chiefly to open to the central region fo the State, an outlet both to a northern and southern market. It will diverge from the Wabash and Erie Canal at the most suitable point between Fort Wayne and Logansport ; thence passing the fertile valleys of th Mississinewa and White rivers to the national road ; thence down the west fork to the Ohio river at Evansville. The southern portion of this canal passes through a country abounding in coal and probably iron. The whole length of the canal will be about 290 miles.

It is proper to remark here that about 110 miles of this route, next to the Ohio, will be common both to the Central and the Wabash and Erie Canals, inasmuch as it will form the outlet for both. It will be perceived also, that these canals will form a perfect water communication between Lake Erie and the Ohio river at Evansville by two different routes, after it passes Fort Wayne, one passing down the valley of the Wabash, and the other through the valley of the Mississinewa and White river, passing the seat of government at Indianapolis These canals will open a *mine* of far more value to Indiana than mines of gold.

3d. The White water Canal.—The chief object of this improvement is to convey to market the surplus agricultural productions of a very fertile and well cultivatad district of country. It commences at the national road in Wayne county near the east line of the State, and passes down the White water valley to Lawrenceburgh on the Ohio river, a distance of 76 miles. It is however provided in the bill, that the north end of this canal shall at some future day be connected with the Central canal in Delaware county, thus making another connection between the Ohio river and Lake Erie, through the White water, the Central, and the Wabash and Erie canals. This connection is required to be canal if that mode be practicable, but if not, by a Railroad.

4. The Madison and Lafayette Railroad. —This work commences at the town of Madison, on the Ohio, and extends through the rich country drained by the east fork of White River to Indianapolis, and thence to Lafayette on the Wabash and Erie

Canal ; crossing, as it does at the seat of Government, both the central canal and the national road, it will receive the travellers which these works will concentrate at that point, and convey them in five hours to the Ohio. The constant intercourse which must ever be maintained by business men and others, in the interior, with the Ohio River, will, it is believed, cause sufficient travelling to sustain this road. Some of the products of the state will doubtless be conveyed to market on the road, though for those of a heavy and bulky nature, which may be raised near the centre of the state, it is supposed that the canal will afford the cheapest conveyance, and therefore be preferred. The merchandise designed for the interior, especially that which may be brought down the Ohio, will be conveyed on this road, and will form a source of considerable revenue. The length of the road will be about 160 miles.

5th. The Jeffersonville and Crawfordsville road.—This will connect the Ohio river at a point opposite Louisville, with the Wabash and Erie canal, by a route passing nearly parallel with the Madison and Lafayette Railway, though so far from that road as to depend for its trade and business upon a different district of country. This road will form the channel of trade and intercourse, both to the north and south, for a large district of the state, embracing several fertile and well-improved counties. The route of this road, crossing as it does the main vallies and ridges of the state, is so undulating as to render it questionable whether a railroad or Macadamized road would be most beneficial to the country. The law gives the preference to a railroad, and directs further examinations and surveys for this mode of improvement ; but if, after full investigation, the Board of Internal Improvement should find the country too hilly for a railroad, they are, in that case, directed to construct a Macadamized road. The road will be about 158 miles in length.

6. The new Albany and Vincennes Macadamized Road. This improvement will connect the Ohio River at New Albany (near Louisville) with the Wabash River at Vincennes, crossing the central canal. The route being transverse to the main vallies which drain the country, and consequently very undulating, a Macadamized road was thought to be more beneficial to the country than a railroad with such extreme ascents and decents. The course cf this road has long been the main route for travellers who pass by land from Kentucky, or the southern states, into Illinois or Missouri. It is believed, therefore, that besides subserving the interest and wants of the country through which it passes, it will also be important to the country as a general thoroughfare. The road will be about 104 miles in length.

7. The Michigan and Erie Canal or Railroad. This improvement is designed to complete the connection between the south end of Lake Michigan and the west end of Lake Erie. The work will unite with the Wabsah and Erie Canal, near Fort Wayne, and extend thence through

the beautiful and fertile valies of the Elk hart and the Big St. Joseph to Michigan city. The law directs the connexion to be formed by canal, if found practicable, and if not, by railroad.

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## CHAPTER VI.

### § 3. *Experiments on the Effects of the Lead.*

The foregoing calculation gives us the loss of power produced in the engine in consequence of the lead.

However, no research having as yet been made on the subject, every thing is at present regulated by opinion alone. There are some engine builders that give no lead at all ; others only $\frac{1}{16}$, or $\frac{1}{8}$ in. at most ; others, on the contrary, give $\frac{5}{8}$ in. or more. Although the lead, if moderately used undoubtedly facilitates the working of the engine, it is also evident, that if carried too far, it must at last stop its effect. For that reason, we resolved to undertake some experiments on the subject.

In our research, we first made use of the LEEDS engine, and we made the three experiments of the 15th of August, related above (Chap. V. Art. VII. § 1) ; the first with a lead of $\frac{1}{8}$ in. ; the second with no lead ; and the third, with a lead of $\frac{3}{8}$ in. But as the change in the load, in the pressure, and in the inclination of the road, caused naturally much complication in the results, we soon gave up that engine, and took in its place the VESTA. An ingenious apparatus, invented by Mr. J. Gray, of Liverpool, and fixed to this engine, made it easy to change the lead without interrupting the journey ; so that, with the same load, and on the same spot, the engine could be tried successively with different leads. This effect was produced by means of three notches, placed more or less backward cn the eccentric, and on which the driver might be brought at will, by means of the common catching lever. The first of these notches gave a lead of $\frac{1}{8}$ in., the second of $\frac{3}{8}$ in., and the last corresponded with a lead oi $\frac{5}{8}$ in. To make the difference more remarkable, we endeavored to obtain a comparrison between the first and the third of these positions of the slide.

The reader will recollect that the VESTA engine has the following proportions :—

| | |
|---|---|
| Cylinders - - - - - - | $11\frac{1}{4}$ in. |
| Stroke of the piston - - - | 16 in. |
| Wheel - - - - - - - | 5 ft. |

I. On the 16th of August 1834, arriving with the engine and a train of 20 wagons at the foot of the inclined plane of Whiston, the inclination of which is $\frac{1}{18}$, all the train was taken off except the seven first wagons, weighing together 34.43 t., and with the tender, 39.93 t. ; and the engine endeavored to ascend the plane with that load.

The lead was first regulated at $\frac{5}{8}$ in. Arrived at the foot of the plane with an acquired velocity of 10 miles an hour, the engine continued its motion for some time, but slackened visibly ; and, after having travel-

led ¾ mile, it stopped; the pressure being 23¼ lbs. by the balance.

The lead was reduced to ⅛ in. The engine set off again, and reached the top of the plane with a velocity of 14 complete strokes of the piston per minute, the pressure by the balance being reduced to 23¼ lbs.

II. In the evening of the same day, the engine having taken to the same place a train of eight loaded wagons, and 12 empty ones, the eight wagons alone were left attached, their aggregate weight being 27.05 t., and with the tender, 32.05 t. With that load it began the ascent of the plane with an acquired speed of 10 miles an hour.

Lead, ⅝ in. The engine arrived at the top without stopping. Pressure at the ballance, 23 lbs. Velocity, 46 complete strokes of the piston per minute.

III. The engine having returned to the bottom with the same eight wagons, six empty ones were attached behind them, making with the loaded wagons a total weight of 43.18 t., and tender included, 48.18 t.

This load was too much for the engine, even with its smallest lead. Pressure, 23 lbs. Two of the empty wagons were taken off.

IV. The engine then drew a train of eight loaded wagons and four empty ones, making together a weight of 34.05 t., and tender included, 39.05 t.

A lead of ⅝ in. was given; the engine was unable to start on the plane.

The lead was reduced to ⅛ in.; the engine started, and augmented gradually its velocity, giving successively 11 strokes of the piston per minute; then 11 again, then 14, and then 17.

The lead was once more tried at ⅝ in.; the engine stopped again.

The lead of ⅛ in. was resumed; the train started again. Pressure during the whole experiment, 23 lbs. by the balance.

V. The train continuing to ascend, two more empty wagons were taken off; there remained then, in all, eight loaded and two empty ones, weighing together 30.38 t., and with the tender, 35.38t.

Lead, ⅝ in. The engine stops; pressure, 23 lbs. by the balance.

Lead, ⅛ in. It starts again; same pressure.

VI. At last one more empty wagon is taken off, and the weight of the train is reduced to 28.55 t., and tender included, to 33.55 t.

Lead, ⅝ in. The engine stops; pressure, 23 lbs. by the balance.

Lead, ⅛ in. It starts again, and reaches the top, although, in consequence of the length of the experiment, the pressure diminishes by degrees from 23 to 21½ lbs. by the balance.

The engine executed thus, at 21½ lbs. pressure, what, with a lead of ⅝ in., it could not execute with a pressure of 23 lbs.

This series of experiments gives us very nearly the exact measure of the power of the engine in both cases, or the loss of power resulting from the difference in the lead.

## § 4. Table of the results obtained in these Experiments.

In order to place these experiments together before the eyes of the reader, we unite them in the following table:—

**EXPERIMENTS ON THE EFFECTS ON THE LEAD.**

| Name and designation of the Engine. | Number of the Experiment. | Load of the Engine tender included. | Lead ⅝ inch. | | Lead ⅛ inch. | |
|---|---|---|---|---|---|---|
| | | | State of the motion. | Effective pressure in pounds per square inch, by the balance. | State of the motion. | Effective pressure in pounds per square inch, by the balance. |
| | | tons. | | lbs. | | lbs. |
| VESTA, Cylinders 11¼ in. | III. | 48.18 | stopped | 20.23 = 56.5 | stopped | 20.23 = 56.5 |
| Stroke ... 16 in. | I. | 39.93 | stopped | 20.23.5 = 58 | star.agn. | 20.23.5 = 57.25 |
| Wheel ... 5 ft. | IV. | 39.05 | stopped | 20.23 = 56.5 | star.agn. | 20.23 = 56.5 |
| Weight ... 8.71 t. | V. | 35.38 | stopped | 20.23 = 56.5 | star.agn. | 20.23 = 56.5 |
| Friction .. 187 lbs. | VI. | 33.55 | stopped | 20.23 = 56.5 | star.agn. | 20.21.5 = 52 |
| | II. | 32.05 | contin-ued its motion. | 20.23 = 56.5 | used its motion. | 20.23 = 56.5 |

According to those experiments, all that an engine can do with a lead of ⅝ in., is to draw a load weighing, without the tender, 27.05 t.

And with a lead of ⅛ in., it will be able to draw a load weighing, without the tender, 34.05 t.

Thus comparing the *useful effects* of the engine in the two cases, we see that they are in the proportion of 4 to 5, which constitutes in practice a considerable advantage in favor of the smallest lead.

In order, however, to obtain an *absolute* measure of the power an engine is able to display in the two circumstances, we must calculate the total resistance that was opposed to the motion of the piston in each case.

In the first, the engine drew a load, tender included, of 32.05 t. on an inclination of $\frac{1}{80}$. On account of the gravity of the mass on the plane, including 8.71 t. for the weight of the engine, the train was equal, on a level, to a load of 160 t.

In the second case the engine drew on the same inclination a train of 39.05 t., equal to a load of 189 t. on a level.

We see that these numbers agree very nealry with those deduced from calulation. If those given by the experiment seem to be a little larger, the reason is because we reckon the tender at an invariable weight of five tons,—whereas, during this long experiment, the consumption of water and coke must have made it descend considerably below that weight, though we had no possibility of weighing the tender, and consequently we could not take the difference into account. We have said, that when the tender is quite empty, its weight is no more than three tons, which upon a level is two tons less than we reckon here, and makes on the inclined plane at $\frac{1}{80}$, a reduction of eight tons in the load.

We may consequently conclude from experience, as well as from theory, that *the decrease of power occasioned by the lead is in proportion to the resulting decrease in the useful length of the stroke of the piston.*

## §. 5. A Practical Table of the Effects of the Lead.

In order to facilitate practical researches, we shall calculate here, according to the formulæ laid down above, § 2, a table of the effects of the lead, for different engines of the most usual proportions on railways.

By these formulæ, the velocity of the motion with no lead at all being known, that which will result from a certain lead represented by $a$, will be to the first in the ratio of

$$\frac{2}{1+\cos\gamma},$$

but, at the same time, the *maximum* load of the engine will be reduced as if the stroke of the piston were reduced to the length

$$\frac{l}{2}(\cos\gamma+\cos\gamma');$$

The arcs $\gamma$ and $\gamma'$ being determined by the equations,

$$\sin\gamma = \frac{2a+4r}{l'}, \text{ and } \sin\gamma' = \frac{2a}{l'}.$$

The reader will recollect that in these formulæ the signs have the following significations:

$l$, length of the stroke of the piston expressed in feet.

$a$, lead of the slide.

$l'$ length of the range of the slide.

$r$, lap of the slide over the apertures of the cylinder.

These three last quantities may be indifferently expressed in feet or in inches, the equations containing only their ratio.

Applying, then, these formulæ to a series of different cases, we form the following table, which will show, at a glance, how the velocity increases when the lead is augmented. As, on the other hand, in the second column, we could not go beyond the load the engine is capable of drawing with its supposed lead, the same table also shows what diminution in the maximum load corresponds to that increase in velocity. It is with a view to make the comparison between these two effects more conspicuous, that we have extended the table further than the importance of the subject seems otherwise to require.

A PRACTICAL TABLE OF THE EFFECTS OF THE LEAD:

| DESCRIPTION OF THE ENGINE. | Load in gross tons, tender included | Velocity in miles per hour, the lead being | | | |
|---|---|---|---|---|---|
| | | 0. | ¼ in. | ½ in. | ¾ in. |
| | tons. | miles. | miles. | miles. | miles. |
| Engine with cylinders 11 in. or 0.917 ft. | 50 | 31.02 | 31.52 | 32.51 | 34.23 |
| Stroke 16 in. or - - - 1.33 ft. | 100 | 21.68 | 22.02 | 22.72 | 23.92 |
| Wheel - - - - 5 ft. | 141 | 17.39 | 17.66 | 18.22 | 19.18 |
| Friction - - - 120 lbs. | 155 | 16.28 | 16.54 | 17.06 | 0. |
| Heating surface - - 140 sq. ft. | 163 | 15.72 | 15.96 | 0. | 0. |
| Effective pressure in boiler - 50 lbs. | 165 | 15.58 | 0. | 0. | 0. |
| Range of the slide - - 3 in. | | | | | |
| Lap over the appertures - ⅛ in. | | | | | |
| Engine with cylinders 12 in. or 1 ft. | 50 | 27.80 | 28.24 | 29.13 | 30.68 |
| Stroke 16 in. or - - - 1.33 ft. | 100 | 20.05 | 20.37 | 21.01 | 22.12 |
| Wheel - - - 5 ft. | 150 | 15.68 | 15.93 | 16.43 | 17.30 |
| Friction - - - 150 lbs. | 168 | 14.56 | 14.79 | 15.25 | 16.06 |
| Heating surface - - 140 sq. ft. | 183 | 13.72 | 13.94 | 14.38 | 0. |
| Effective pressure in boiler - 50 lbs. | 193 | 13.22 | 13.43 | 0. | 0. |
| Range of the slide - 3 in. | 196 | 13.11 | 0. | 0. | 0. |
| Lap over the apertures - ¼ in. | | | | | |
| Engine with cylinders 13 in. or 1.083 ft. | 50 | 29.03 | 29.49 | 30.42 | 32.03 |
| Stroke 16 in. or - - - 1.33 ft. | 100 | 21.46 | 21.80 | 22.48 | 23.68 |
| Wheel - - - 5 ft. | 150 | 17.02 | 17.29 | 17.83 | 18.78 |
| Friction - - - 165 lbs. | 197 | 14.25 | 14.47 | 14.93 | 15.72 |
| Heating surface - - 160 sq. ft. | 216 | 13.37 | 13.58 | 14.01 | 0. |
| Effective pressure in boiler - 50 lbs. | 227 | 12.91 | 13.11 | 0. | 0. |
| Range of the slide - 3 in. | 231 | 12.75 | 0. | 0. | |
| Lap over the apertures - ⅛ in. | | | | | |
| Engine with cylinders 14 in. or 1.116 ft. | 50 | 29.83 | 30.30 | 31.26 | 32.91 |
| Stroke 16 in. or - - 1.33 ft. | 100 | 22.56 | 22.92 | 23.64 | 24.89 |
| Wheel - - - - 5 ft. | 150 | 18.14 | 12.43 | 19.00 | 20.01 |
| Friction - - - 180 lbs. | 200 | 15.17 | 15.41 | 15.89 | 16.73 |
| Heating surface - - 180 sq. ft. | 229 | 13.85 | 14.07 | 14.51 | 15.28 |
| Effective pressure in boiler - 50 lbs. | 252 | 12.96 | 13.16 | 13.58 | 0. |
| Range of the slide - 3 in. | 265 | 12.50 | 12.70 | 0. | 0. |
| Lap over the apprtures - ⅛ in. | 269 | 12.37 | 0. | 0. | 0. |
| Engine with cylinders 12 in. or 1 ft. | 50 | 26.16 | 26.57 | 27.41 | 28.86 |
| Stoke 18 in. or - - - 1.50 ft. | 100 | 19.85 | 20.16 | 20.80 | 21.90 |
| Wheel - - - - 5 ft. | 150 | 15.99 | 16.24 | 16.75 | 17.64 |
| Friction - - - 165 lbs. | 188 | 13.93 | 14.15 | 14.60 | 15.37 |
| Heating surface - - 160 sq. ft. | 207 | 13.09 | 13.30 | 13.72 | 0. |
| Effective presssure in boiler - 50 lbs. | 217 | 12.69 | 12.89 | 0. | 0. |
| Range of the slide - 3 in. | 221 | 12.53 | 0. | 0. | 0. |
| Lap over the apertures - ¼ in. | | | | | |

From these results we see that too great a lead detracts a considerable portion from the power of the engine. It is therefore necessary not to exceed, in that respect, certain limits.

It is, besides, easy to know the lead, or to regulate it at any degree.

After having opened the chamber situated under the chimney, and taken off the top of the slide-box, in order to see the slides work, the engine must be pushed gently forward on the rails, until the crank of the axle be perfectly horizontal.

Then the piston is at the bottom of the cylinder. If at that moment the passages which the slide opens to the steam be measured, it will give exactly the lead.

If we wish to alter the lead, we keep the crank in the same position, and loosening the driver which is fastened to the axle only with a screw, we turn the exccentric, until the slide, which moves at the same time, opens the passage as much as is wanted. Then we replace the driver so as to fix the

exccentric in that position. This operation concluded, it is clear that whenever the crank is horizontal, or the piston ready to begin its stroke, the slide will open the passage to the degree required.

There are some ways of altering the lead without opening each time the chimney chamber; but they are not quite exact, and some of them are injurious to the engine.

In the experiments we have related above on the velocity of the load of the engines, the *Vesta* engine was the only one in which the lead was considerable enough to have a remarkable effect on the speed.

## CHAPTER VII.
OF THE CURVES AND INCLINED PLANES.

### ARTICLE I.
OF THE CURVES.

§ 1. *Of the conical form of the Wheels and surplus of elevation of the Rails, calculated to annul the effect of the Curves.*

We have considered the dispositions proper to the engine, that may either favor or impede its effect. We have still to examine two external circumstances that may have a similar influence on the motions.

The curves offer on the railways an additional resistance, which is so much the greater according as the degree of their incurvation is more considerable.

The wagons being of a square form, tend to continue their motion in a straight line. If, therefore, they are obliged to follow a curve, the flange of the wheel does no longer pass in a tangent along the rail without touching it, as it does in a direct motion. The rail, on the contrary, presents itself partially crosswise before the wheel, and opposes thus its progress, by forcing it to deviate constantly from its direction.

Moreover, the wheel that follows the exterior rail of the curve has naturally more way to travel than that which follows the interior rail. Now in the wagons at present in use, the two wheels of the same pair are not independent of one another. They are fixed on the axletree that turns with them. If therefore the road travelled by one of the two wheels be less than that of the other, the latter one must necessarily be dragged along without turning on the difference of the two roads.

Finally, on passing the curves, the wagons are thrown by the centrifugal force of the motion against the outward rail, the result of which is a lateral friction of the flange of the wheel against the rail, which does not exist in the direct motion.

It is impossible to construct the wheels of the wagons and the railway itself in such a manner that these three additional causes of resistance may be destroyed. The mode we are going to describe, in order to obtain that effect, is that which is already known; viz., the conicalness of the tire of the wheel, and a greater elevation of the outward rail at the place of the curve. But those means have until now been employed only by approximation, and fulfil more or less imperfectly the intended purpose. By sumitting them to calculation, we trust we shall be able to deduce general rules, which will make us certain that the required effect will be obtained.

The particular resistance owing to the passage of the curves, is composed of two distinct parts, as to their causes and their effects.

The first, according to what we have seen above, is occasioned by the waggons being obliged to turn along the curve, which produces an opposition of the rail to the motion, and a dragging of the wheel.

The second is owing to the centrifugal force, and produces the friction of the flange of the wheel against the rail.

The first of these two resistances will evidently be corrected, if we succeed in constructing the wheels of the wagon in such a manner that the wagon may follow of itself the curve of the railway. For that, it will be sufficient to make the wheel slightly conical with its greatest diameter inside; that is to say, towards the body of the wagon, as appears on the engine in fig. 2.

By that disposition, when the centrifugal force throws the wagon on the outside of

the curve, the wheel on that same side will then rest on a tire of a larger diameter. Two effects will result from this. The wagon will no longer tend to follow a straight line. One of its wheels growing larger than the other, will, on the contrary, have a tendency to turn in the direction of the curve. Besides which, the two coupled wheels will naturally travel different lengths of road without any dragging on the rail.

This form of the wheel and its effects being very well understood, we have first to determine what difference of diameter must be created between the two wheels, in order that the wagon may turn of itself with the curve, and how much the wagon must deviate on one side in order to produce that differe ce of diameter. Then we shall see how the railway must be constructed, in order that the centrifugal force of the motion produce of itself that lateral deviation. It will thus be clear, that, those different conditions being fulfilled, the first species of resistance of the curve will be destroyed by the motion itself. Coming to the friction of the flange of the wheel against the rail, we shall determine what degree of conicalness the wheel must have, in order that, even in passing over the most abrupt curve of the railway, the lateral deviation of the wagon may never go so far as to put the flange in contact with the side of the rail. In this way, both by the disposition of the rails and by the form of the wheels, the two species of resistance will be destroyed.

Let us suppose that $mm'$ and $nn'$ (fig. 28) be the two lines of rails of the way. In order that the wagon may follow without effort the curve of the way, it is necessary that, while the outside wheels describes the arc $mm'$, the inside wheel describes of itself the arc $nn'$, which terminates at the same radius as the first. If, therefore, the length $mm'$ represent a circumference of the outside wheel, $nn'$ must also be a circumference of the inside wheel, and the diameters of the two wheels must be in a certain proportion for that effect to be produced.

Let D be the diameter of the first wheel, and D' that of the second, $\pi$ being the ratio of the circumference to the diameter, we shall have—

$$mm' = \pi\,D, \text{ and } nn' = \pi\,D'.$$

Now the two arcs being both terminated by the same radius, we have—

$$\frac{mm'}{nn'} = \frac{mo}{no}.$$

If we express the radius of curvation or by $r$, and the half breadth of the road by $e$, this proportion may be expressed thus :—

$$\frac{mm'}{nn'} = \frac{r+e}{r-e};$$

then,

$$\frac{D}{D'} = \frac{r+e}{r-e}$$

and, finally,

$$D - D' = D\left(1\,\frac{r-e}{r+e}\right) = \frac{2\,e\,D}{r+e}.$$

This equation shows the difference that must exist between the diameters of the wheels, that the required effect may be obtained.

Our intention being to produce that effect, by pushing the wagon aside on the road, the question is, how much the wagon must be laterally displaced.

This point depends evidently on the degree of conicalness of the wheel.

At Liverpool, the wheels of the wagons have 3 ft. diameter at the interior part or near the flange, and 2 ft. 11 in. at the exterior part. The wheel is originally cylindrical, but the conical form is produced by the addition of a second tire, the breadth of which, not including the flange, is $\frac{1}{2}$ in. less on one side than on the other. Fig. 29, represents the section of that tire on a scale of $\frac{1}{4}$. Its breadth being $3\frac{1}{2}$ in., we see that its conical inclination is $\frac{1}{2}$ in. on $3\frac{1}{2}$ in. or $\frac{1}{7}$.

Let us suppose in general the inclination of the tire expressed by $\frac{1}{a}$. The two wheels running originally upon equal tires, in order that the difference $D - D'$ be produced in their diameters, by the displacing of the tire on the rail, this lateral displacing of the wheel must evidently be

$$\tfrac{1}{4}\,a\,(D - D');$$

for the inclination of the tire being $\frac{1}{a}$, this displacing will produce on the thickness of the tire, or on the radius of the wheel, a difference of

$$\tfrac{1}{4}\,(D - D'),$$

which will make on the diameter

$$\tfrac{1}{2}\,(D - D').$$

This difference on the diameter will be produced in plus on the outside wheel, and as an equal difference, but in a contrary sense, that is to say, in minus, will be produced on the inside wheel ; the result will be a total difference of $D - D'$ between the actual diameter of the two wheels, as we have said.

Thus the lateral motion to be produced is

$$\tfrac{1}{4}\,a\,(D - D) = \frac{a\,e\,D}{2\,(r + e)}.$$

We know at present what must be the lateral displacing of the wagon, in order to destroy the first species of resistance. The question now is, to make use of the centrifugal force to produce that effect. It is its natural tendency ; but it is evident that that force must produce exactly the necessary displacing, else the defect would by no means be corrected.

If we represent by $r$ the radius of curvation, by $V$ the velocity of the motion, and by $m$ the mass of the body moved, the centrifugal force produced on the curve will be, as is known, expressed by

$$f = m\,\frac{V^2}{r}.$$

But P being the weight of that same body, and $g$ the accelerating force of gravitation, we have

$$P = gm, \text{ from whence } m = \frac{P}{g};$$

thus

$$f = \frac{P}{g}\,\frac{V^2}{r},$$

which is the expression of the centrifugal force of a body of a given weight P, moving with a velocity V, on a curve the radius of curvation of which is $r$.

In this expression, $g$ is the accelerating force of gravitation, or the double of the space passed over in the unit of time by a body falling in a vacuum. Taking a second for the unit of time, and a foot for the unit of space, we have $g = 32$. Referring to the same units the velocity V, and the radius of curvation $r$, we shall have the measure of the centrifugal force expressed by its proportion to the weight P, or represented by a weight.

Let us suppose, for instance, that the velocity of the motion be 20 miles an hour, or 29.3 ft. per second, and the radius of the curve 500 ft. ; we shall have

$$f = P \times \frac{\overline{29.3}^2}{32 \times 500} = \tfrac{1}{19}\,P.$$

So in that case the centrifugal force will be the nineteenth part of the weight of the body in motion.

The sense of the signs being now well understood, we return to the general expression of the centrifugal force.

$$f = P \times \frac{V^2}{gr}.$$

The effort of this force exerting itself in the direction of the radius, its effect will be to push all the wagons out of the curve. If the two sides of the railway are of equal elevation, the wagons will be stopped in the lateral motion only by the friction of the flange of the wheel against the rail. But if we give to the outward rail a surplus of elevation above the inward one, it is clear that, in increasing sufficiently that elevation, we shall be able to master at last the centrifugal force, in such a manner as to permit it only to produce just the displacing we want. In fact, by raising in that manner the outward side, we change the railway in an inclined plane. The wagons placed on that plane ought, by virtue of their gravity, to slip towards the lower rail. On the other hand, the centrifugal force pushes them against the outward rail, which is the highest. We create, then, by that means, a counterpoise to the centrifugal force.

Let us call $y$ the surplus of elevation given to the outward rail (fig. 30) ; $2e$ being the breadth of the way, the inclination of the plane on which the wagons are placed, is $\frac{y}{2e}$. On this plane, the gravity of a body, the weight of which is P, is expressed by

$$P \times \frac{y}{2e}.$$

This gravity, as we have seen, tends to make the wagons fall within the curve, while the centrifugal force pushes it without. If, therefore, we select the height $y$, such as may give

$$P \times \frac{y}{2e} = P \times \frac{V^2}{gr},$$

the train, in passing over the curve, will experience no derangement from its original position, because the gravity and the centrifugal force will equilibrate.

But, as for motives already explained, we require the wagon to be pushed aside, a certain quantity expressed by

$$\frac{ae\,D}{2\,(r+e)}=\mu,$$

we must endeavor to find out what is the necessary inclination.

Let us then suppose the train already displaced as much as required. Let us imagine, for instance, that the train has been pushed from the position *ab* to the piston *cd* (fig. 30;) that is to say, that the point of the inside wheel that was at *a* be come to *c*, at the distance μ from the first point, and that at the same time, the point of the outward wheel that was at *b*, be come to *d*. In this situation, the inclination of the plane on which the train is, will be $\frac{y}{2e-\mu}$.

Moreover, the conical inclination of the wheels shows that on the outward side of the curve the wheel will have increased its diameter by a certain quantity, in consequence of the lateral deviation; while on the interior side, it will on the contrary, have diminished of an equal quantity. The tire of the wheel having a supposed inclination of $\frac{1}{a}$, a lateral motion represented by μ, must have produced on each wheel a difference in height represented by $\frac{\mu}{a}$. The effect of that variation of the wheels being to incline the wagon on one side, so that it is raised on one side of the quantity $\frac{\mu}{a}$, and lowered on the other of the same quantity $\frac{\mu}{a}$; the result is a total inclination of $\frac{2\mu}{a}$, which must thus be added to the inclination already produced by the difference of level between the rails.

Consequently the outward side of the wagon will be raised above the interior side of a quantity equal to $y+\frac{2\mu}{a}$; and as the base which separates the two bearing points is measured by $2e-\mu$, the final result is that the wagon will be in the same case as if it were placed on a plane, the inclination of which should be

$$\frac{y+\dfrac{2\mu}{a}}{2e-\mu}.$$

In order that the centrifugal force may maintain the wagon in that position without throwing it out or letting it fall in, that is to say, so that there may be an equilibrium between the gravity on the plane and the centrifugal force, we must have

$$P\times\frac{y+\dfrac{2\mu}{a}}{2e-\mu}=\frac{PV^2}{gr},$$

or

$$y=\frac{V^2}{gr}(2e-\mu)\;\frac{}{}-\frac{2\mu}{a},$$

Substituting for μ its value, this equation becomes

$$y=\frac{eV^2}{gr}\left\{2-\frac{aD}{2\,(r+e)}\right\}\frac{eD}{r+e}.$$

Knowing, then, the conical form and the diameter of the wheels, as well as the average velocity of the motion and the breadth of the way, this expression will give the surplus of elevation *y* that suits the radius of curvature *r*.

Let us suppose that we have to employ the dimensions of the railway and wagons of Liverpool; that is to say, that we have:

V, average velocity, 20 miles an hour, or 29.3ft. per. second.

$\frac{1}{a}$, inclination of the tire of the wheel, $\frac{1}{7}$.

*e*, half breadth of the way, 2.35 ft.

D, diameter of the wheel at its right place on the rail, 3 ft.

If we wish to construct on that railway a curve of 500 ft. radius, on which the wagons may experience no additional resistance the equation will give

$$y=0.236\text{ ft. or in inches, } y=2.83\text{ in.}$$

We must, therefore, for that curve, with that wheel and that average velocity, give a surplus of elevation of 2.83 in. to the outward rail.

Adopting the surplus of elevation of the rail deduced from that equation, we render it impossible, the first species of resistance, which the passage of the curves tend to produce. However, as we only destroy that resistance by a certain lateral deviation of the wagon, it might be feared that that deviation might go so far as to make the flange of the wheel rub against the rail, in which case we would only have substituted one resistance for another. This is, therefore, the point we have still to consider.

We have, until now, supposed the inclination $\frac{1}{a}$ of the tire of the wheel to be given *a priori*. But as it is on that inclination that depends the degree of deviation the wagon must undergo on the rails, it must evidently be such that, even on the most abrupt curve of the line, the lateral deviation of the wagon may never be considerable enough to bring the flange of the wheel in contact with the rail.

Now we have seen above, that the necessary lateral deviation is expressed by

$$\mu=\frac{ae\,D}{2\,(r+e)};$$

If, therefore, the wagons have, for instance, a play of 2 in. on the way altogether; that is to say, if, in their regular position, the flanges of the wheels keep on each side at a distance of 1 in. from the rail, the greatest value of the deviation μ, must always be less than 1 in. By that greatest value of μ, we mean the deviation on the most abrupt curve of the line. Consequently, putting for *r* the radius of that curve, and for μ its maximum, 1 in. or $\frac{1}{12}$ of a foot, the equation will give the greatest value that can be given to the quantity *a*, or the least value of the inclination $\frac{1}{a}$.

For instance, on a line, the most abrupt curve of which has 500 ft. radius, with wagons having wheels of 3 ft. diameter, and a play of 1 in. on each side of the way. the equation shows that the least inclination one ought to give to the tire of wheel is $\frac{1}{12}$; but a more considerable inclination will answer, *a fortiori*.

On the Liverpool and Manchester Railway, the most abrupt curve, which is the one at the entrance of Manchester, has a radius of 858 ft. This results a conical inclination of $\frac{1}{12}$, and this would answer in all cases; but having said that a greater inclination will fulfil the same object, we are free to adopt a greater inclination, if it suits other purposes better.

It is customary to give an inclination of $\frac{1}{7}$. The motive for making it so considerable, is to prevent all possibility of the flange rubbing against the rail, either in case of a strong side-wind, or in case of some fortuitous defect in the level of the rails, by which the wagons would be thrown on the lower rail. Having seen above that, with an inclination of $\frac{1}{12}$, there would be no danger of the flange rubbing in the curves, that danger will be still more impossible with an inclination of $\frac{1}{7}$.

We conclude that, with wheels having that inclination, the surplus of elevation of the rail which we have determined above, will correct the first species of resistance of the curves without creating the second, and that, consequently, the train will pass over the curves without any diminution of speed.

§ 2. *A Practical Table of the Surplus of Elevation of the outward Rail in Curves, in order to annul the effects of those Curves.*

From what has been said, the surplus of elevation that must be given to the outward rail in the curves, is determined by the following formulæ:

$$y=\frac{eV^2}{gr}\left\{2-\frac{aD}{2\,(r+e)}\right\}\frac{eD}{r+e}.$$

In this equation the signs have the following value:

D, diameter of the wheel expressed in feet.

*r*, radius of the curve expressed in the same manner.

*e*, half of the width of the way expressed in the same.

V, average velocity that is to be given to the motion, expressed in feet per second.

*g*, accelerating force of gravitation, expressed in feet per second, or $g=32$ feet. $\frac{1}{a}=\frac{1}{7}$; consequently, $a=7$.

*y*, surplus of elevation to be given to the outward rail of the curve, over the inward rail, expressed in feet and decimals of feet.

Solving these formulæ in the most usual cases on railways, we make out the following table which dispenses with all calculations in that respect.

**A PRACTICAL TABLE OF THE SURPLUS OF ELEVATION TO BE GIVEN TO THE OUTWARD RAIL IN THE CURVES, IN ORDER TO ANNUL THE RETARDING EFFECT OF THE CURVES.**

| Radius of the curve, in feet. | Surplus of elevation to be given to the rail, in inches, the velocity of the motion in miles, per hour, being | | |
|---|---|---|---|
| | 10 miles. | 20 miles. | 30 miles. |
| ft. | in. | in. | in. |
| 250 | 1.14 | 5.60 | 12.99 |
| 500 | 0.57 | 2.83 | 6.56 |
| 1000 | 0.29 | 1.43 | 3.30 |
| 2000 | 0.15 | 0.71 | 1.65 |
| 3000 | 0.10 | 0.47 | 1.10 |
| 4000 | 0.07 | 0.36 | 0.83 |
| 5000 | 0.06 | 0.28 | 0.66 |

| Designation of the Wagons and the Way. | |
|---|---|
| Wagon with wheel . . . | 3 ft. |
| Way . . . | 4.70 ft. |
| Play of the wagon on the way, | 0.083 ft. |
| 1 in., or | |
| Inclination of the tire of the wheel ? | |

## ARTICLE II.

### OF THE INCLINED PLANES.

#### § 1. *Of the Resistance of the Trains on Inclined Planes.*

Inclined planes are a great obstacle to the motion on railways.

As soon as the trains reach these inclined planes, they offer a considerable surplus of resistance, on account of the gravity of the total mass that must be drawn up the plane.

Let us suppose a train of 100 t. drawn by an engine. Having seen that on a level the friction of the wagons produces a resistance of 8 lbs. per ton, the power required of the engine will be 800 lbs., when travelling on a level. But let us suppose the same train ascending an inclined plane at $\frac{1}{100}$. On that plain, besides the resistance owing to the friction of the wagons, a fresh resistance occurs, which is the gravity of the total mass in motion on the plane. That gravity is the force by virtue of which the train would roll back if it were not retained; and it is equal to the weight of the mass divided by the number that indicates the inclination of the plane. If, therefore, in this case, the load of 100 t. is drawn by an engine weighing 10 t., the total mass placed on the inclined plane will be 110 t. or 246,400 lbs.; and thus its gravity on the inclined plane, at $\frac{1}{100}$, will be $\frac{246,400}{100}$ lbs. = 2,464 lbs. The surplus of traction required of the engine, on account of that circumstance, is, therefore, 2,464 lbs., and, as we have seen that on a level 1 t. load is represented by 8 lbs. traction, we also see that those 2,464 lbs. re-

present the resistance that would be offered by a load of 308 t. on a level. Consequently the engine which, before, drew 100 t. must now draw 408 t., or at least must exert the same effort as if it drew 408 t. on a level.

This is the manner in which the calculation of the resistance on inclined planes must be established; and we have entered into those particulars, because it frequently happens that, in making the calculation, the gravity of the load is alone considered, without taking into account the gravity of the engine, which ought also to enter for its share.

In speaking of the fuel, we shall see that the inclined planes of the Liverpool Railway, which at first sight appear quite insignificant, oblige, however, the engines to a surplus of work, which amounts to a sixth part of what they would have to do on a level. By this we see how important it is, in establishing a railway, to keep it on as perfect a level as possible. It frequently happens that, by avoiding to level a part of the road, that is to say, to cut through a hill, or to form an embankment through a valley, a great economy is expected. This is, however, a great mistake, for, in most instances, the only economy is that of the first outlay, whereas, the annual augmentation of expense surpasses by far the interest of the capital saved; so that, instead of an economy, we have in reality a greater expense. This additional expense may even, in some cases, go so far as to paralyze completely all the advantages of the undertaking.

In suffering inclined planes to subsist on a line of railway, it not only becomes impossible to lower sufficiently the freight of the goods; but, what is much more important, frequent accidents occur while descending those steep acclivities, the least inconvenience of which is to destroy public confidence in the safety of the conveyance. It is, therefore, necessary to lay down as a principle, that the end to be aimed at in the construction of a railway, is not only to make a smooth road, but likewise a level one. It is, besides, the only way to apply with efficacy the use of locomotive engines.

When, however, it has been impossible to avoid the inclined planes, and when the use of stationary engines has been rejected on account of the interruption they unavoidably cause in the service, there are only two ways that can be resorted to. The loads must either be regulated so that they may not exceed the power of the engine in going up the plane, or it is necessary to give the engines the help of one or more others, according to what is required.

On the Liverpool Railway, the trains of coaches never being very heavy, are seldom above the power of the engines on the most inclined parts of the line, viz. in the two acclivities of $\frac{1}{96}$ and $\frac{1}{89}$. In general, therefore, the engines ascend these inclined planes without help; and during the rest of the trip, on the level or descending parts of the line, their speed is regulated by partially shutting the regulator.

The trains that are too heavy for a single engine, as are commonly those of wagons,

are helped in passing the plane by an engine stationed at the foot of the acclivity, and especially intended for that use. This engine is, consequently, constructed for a slow motion and a considerable power. The cylinders have 12 or 14 in. diameter, with the usual stroke of 16 in., and the wheels have only 4 ft. 6 in. Besides, in order to have more adhesion, the weight of the engine is 12 t. and the four wheels are coupled. These additional engines, working less than the others, require also, in general, much less repairs.

On the Darlington Railway, the acclivities are much too numerous for an additional engine to be placed at each of them. The load of the engine must therefore be limited so that it may ascend with that load the most inclined of the planes.

The locomotive engines acquire, however, a considerable augmentation of power, at the moment of their passage on an inclined plane, because their speed being suddenly considerably reduced, the cylinders consume a smaller quantity of steam. The fire, strongly excited by the preceding rapidity of the engine, continuing to furnish the same quantity of steam, a great part of it must escape through the valve. But the passage of the valve is too narrow to emit freely all that steam. Besides, the spring that presses on the valve opposes more and more resistance, in proportion as the steam tends to raise it higher, in order to get a wider passage for itself. The consequence is that the steam, not being able to escape as quickly as it is generated, suffers an increase of pressure in the boiler.

This increase of pressure evidently depends on several circumstances: the size of the valve, the evaporating power of the boiler, the previous excitation of the fire, and finally the length of the lever at the extremity of which the spring-balance acts. In some engines this increase may amount to 10 lbs. per square inch, as we have remarked in speaking of the pressure.

In that case, if the usual effective pressure of the engine be 50 lbs. per square inch, it may, on ascending the inclined plane, increase to 60 lbs., that is to say, in the proportion of $\frac{1}{5}$, which is considerable. This must, therefore, be taken into account when it is required to calculate the load the engines are able to draw on these planes. But it is necessary to observe that this is effectual only when the inclined planes are not of too considerable an extent, because, in that case, the fire ceasing to be excited in the same proportion, the surplus of effect will be reduced. The weight of the engine must, besides, always give sufficient adhesion of the wheel to the rail, as we shall explain in the following Chapter.

There is also another circumstance in which the engines are obliged to exert an additional effort. That is at the moment of starting. We have seen, in fact, that the power which, when the motion is once created, need only to be constantly equal to the resistance, must, on the contrary, surpass it at the instant that it is to put the mass in motion. The reason is plain: in the first place, it is only necessary to maintain the speed; in the other it must be

created and maintained. It is this additional effort on the part of the moving power which is improperly called *vis inertiæ*, because it is attributed to a particular resistance residing in the mass.

The starting is, therefore, a difficult task for a locomotive engine heavily loaded. However, at that moment the engine acquires, as well as on the inclined planes, a considerable increase of power. Here again the slowness of the motion produces two effects. The pressure in the cylinder grows equal to the pressure in the boiler, which is itself augmented by the effect of the spring-balance. But, notwithstanding this twofold advantage, the difficulty of starting still remains so great for considerable loads, that we should always advise giving in that point a slight declivity to the way. By that means the trains would be set in motion with more ease at the departure, and it would not be necessary at their arrival to make use, in order to stop them, of the powerful brakes, the effect of which is certainly as destructive to the wheels of the wagons as to the rails.

### § 2. *Practical Table of the Resistance of the Trains on Inclined Planes.*

In the preceding paragraph, we have seen in what manner the resistance of the trains on the inclined planes must be calculated. The following table presents the result of that calculation in the cases which occur the most frequently on the railways.

It is clear that, by the weights inscribed in the following table, it is only intended to show the resistance offered by the train, and not the weights the engines are able to draw, those weights being limited either by the power of the engine, as we have explained

A PRACTICAL TABLE OF THE RESISTANCE OF THE TRAINS ON INCLINED PLAINS.

| Designation of the Engine. | Weight of the trains in gross tons, tender included | Load in gross tons which on a level would offer the same resistance the inclination of the plane being | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\frac{1}{5}$ | $\frac{1}{7}$ | $\frac{1}{10}$ | $\frac{1}{20}$ | $\frac{1}{15}$ | $\frac{1}{10}$ |
| Engine weighing 8 t. | 25 | 44 | 48 | 56 | 71 | 87 | 117 |
| | 50 | 83 | 91 | 105 | 131 | 158 | 212 |
| | 75 | 122 | 133 | 153 | 191 | 236 | 307 |
| | 100 | 161 | 176 | 201 | 251 | 302 | 402 |
| | 125 | 200 | 218 | 249 | 311 | 373 | 497 |
| | 150 | 239 | 261 | 298 | 371 | 445 | 592 |
| Engine weighing 10 t. | 25 | 45 | 50 | 58 | 74 | 91 | 123 |
| | 50 | 84 | 93 | 107 | 134 | 162 | 218 |
| | 75 | 123 | 135 | 155 | 184 | 234 | 313 |
| | 100 | 162 | 178 | 203 | 254 | 306 | 408 |
| | 125 | 201 | 220 | 251 | 314 | 377 | 503 |
| | 150 | 240 | 263 | 300 | 374 | 449 | 598 |
| | 175 | 279 | 305 | 348 | 434 | 521 | 693 |
| | 200 | 318 | 348 | 396 | 494 | 592 | 788 |
| Engine weighing 12 t. | 25 | 46 | 51 | 60 | 77 | 95 | 129 |
| | 50 | 85 | 94 | 109 | 137 | 166 | 224 |
| | 75 | 124 | 136 | 157 | 197 | 238 | 319 |
| | 100 | 162 | 179 | 205 | 257 | 310 | 414 |
| | 125 | 202 | 221 | 253 | 317 | 381 | 509 |
| | 150 | 241 | 264 | 302 | 377 | 453 | 604 |
| | 175 | 280 | 306 | 350 | 437 | 525 | 699 |
| | 200 | 319 | 349 | 398 | 497 | 596 | 794 |
| | 225 | 358 | 392 | 446 | 557 | 668 | 889 |
| | 250 | 397 | 434 | 494 | 617 | 740 | 984 |

elsewhere, or by its adhesion, as shall be mentioned in the following Chapter.

This table, assimilating the trains drawn on inclined planes, to trains drawn on a level, gives the means to learn by the former tables, either the loads the engines will be able to draw on given inclinations, or, *vice versa*, the inclined planes the engines will be able to ascend with given loads.

## CHAPTER VIII.
### OF THE ADHESION.

#### § 1. *Measure of that Force.*

The series of experiments we have described above on the velocity and load of the engines, solves also another question in regard to the motion of locomotive engines of which we have not yet spoken. That is the adhesion of the wheel to the rails.

We have remarked in describing the engine, that the power of the steam being applied to the wheel, the engine is in the same situation as a carriage which is made to advance by pushing at the spokes. Thus, as in that action, the only fulcrum of the moving power exists in the adhesion of the wheel to the rail, if that adhesion is not sufficient, the force of the steam will indeed make the wheels turn, but the wheels, but the wheels slipping on the rails instead of adhering to them, will revolve, and the engine will remain in the same place.

The more considerable the train the engine draws, the more power it must employ, and the more resistance it must consequently find in the point on which it rests, for executing the motion. It was therefore to be feared, that with considerable trains, the engines would be unable to advance; not that the force would be wanting in the moving power itself, but in the fulcrum of the motion.

The experiments related above, establish the measure of that adhesion in the fine season of the year. Among all these experiments, not one is to be found where the motion has been stopped or even slackened for want of adhesion, and nevertheless we see loads that amount to more than 200 t.

If we take, for instance, the first experiment made with the FURY, on July 24; during a part of the journey, that engine drew 244 t. The engine advancing with that load, the adhesion must necessarily have been sufficient. Now the weight of the FURY is 8.20 t,, and that weight is divided in such a manner, that 5.5 t. are supported on the two hind wheels, which are the only working wheels, the others not serving to push the engine forward, but only to carry it. We have thus a weight of 5.5 t. drawing 244 t., or a load 44½ times as considerable as itself. The result of this is, that an engine having its four wheels coupled, and which consequently adheres by its whole weight, is able to draw a load 44½ times its own mass.

We have said that the FURY engine adhered only by two of its wheels. On the Liverpool Railway that disposition is generally adopted for all trip engines, because the adhesion of two wheels is sufficient for the loads they have to draw. As for the

helping engines, the work by the adhesion of their four wheels, as has been said elsewhere. The ATLAS is the only one of the former class that differs from the others in that respect. This engine has six wheels, four of which are of equal size, and worked by the piston. The two others, which are smaller, and have no flange, can be raised out of contact with the rails, by the action of the steam on a moveable piston. That ingenious arrangement, which may have more than one useful application, in permitting the weight of an engine to be distributed upon six wheels, without making the engine more embarrassing than if it had only four, is due to Mr. J. Melling, of Liverpool, who, in this instance, made use of it in order to give the engine a much larger firebox, and consequently the power of generating a greater quantity of steam.

We have now expressed the adhesion, by giving the measure of its effects; but the power itself may be expressed in a direct manner. The load of 244 t. produced a resistance, or required a traction of 1,952 lbs.; the adhesion was thus equal at least to 1,952 lbs., else the wheel would have turned without advancing. Now the adhering weight was 5.5 t. or expressed in pounds 12,320 lbs.; we see then that the force of adhesion was equal to about $\frac{1}{6}$ of the adhering weight. Considering that every 8 lbs. force corresponds with the traction of a ton on a level, this expression is exactly similar to the first.

In winter when the rails are greasy and dirty, in consequence of damp weather, the adhesion diminishes considerably.—However, except in very extraordinary circumstances, the engines are always able to draw a load of 15 wagons, or 75 t., tender included, that is to say, 14 times their adhering weight. In other words, the resistance of 75 t. being 600 lbs., the force of adhesion is always at least $\frac{1}{20}$ of the adhering weight.

Adhesion being indispensable to the creation of a progressive motion, two conditions are necessary in order that an engine may draw a given load. 1st. That the dimensions and proportions of the engine and its boiler enable it to produce on the piston, by means of the steam, the necessary pressure, which constitutes what is properly termed the power of the engine: and, 2nd, that the weight of the engine be such as to give a sufficient adhesion to the wheel on the rail. These two conditions of power and weight must be in concordance with each other; for, if there is a great power of steam and little adhesion, the latter will limit the effect of the engine, and there will be steam lost; if, on the other hand, there is too much weight for the steam, that weight will be an useless burthen, the limit of load being in that case marked by the steam.

#### § 2. *Of the Engines employed on Common Roads.*

The considerable loads that have been drawn by the engines in the experiments described above, ought to remove the fears of such persons as suppose that the wheels of locomotive engines on railways are con-

stantly apt to slip, and who endeavor to remedy that imaginary defect by employing the engines on common roads, without having ascertained whether the adhesion will be more considerable.

We see here a locomotive engine on a railway, drawing 244 t. by the force of its steam, and not less than 75 t. by its adhesion. Its loads are thus always comprised between those two limits.

On a common road, where the resistance of traction is very considerable, not one of the above-mentioned engines would be able, by the force of its steam, to draw a weight of 75 t., much less ever to attain 244 t. The loads will therefore always, and in every circumstance, remain below what they would be on a railway. Of what importance is it, in fact, whether the moter gains in regard to adhesion, which is only an inert force, if the power of the steam do not enable it to profit of that advantage?

We say that an engine that draws on a railway a load of 75 t. *at least*, will never be able, on a common road, to draw that same load *at most*.

Let us in fact examine the same engine, with the same weight and same pressure, placed in those two different circumstances.

The experiments made by Mr. Telford, on the draft of carriages on different sorts of roads, prove that on the road from Liverpool to Holyhead, *the best in England*, the force of traction necessary to draw a weight of one ton is as follows:—*

|  | lbs. |
|---|---|
| 1st. On a well-made pavement - - | 33 |
| 2nd. On a broken stone surface on old flint road - - - - - - - - - - | 65 |
| 3rd. On a gravel road - - - - - | 147 |
| 4th. On a broken stone road, upon a rough pavement foundation - - - | 46 |
| 5th. On a broken stone surface upon a bottoming of concrete, formed of Parker's cement and gravel - - | 46 |
| Mean - - - - | 67 |

On a railway, a ton requires only 8 lbs. traction. Thus, on the Holyhead road, the traction of a ton requires eight times as much force as on a railway.

The consequence is, that the FURY engine, for instance, which by the effect of its 65 lbs. effective pressure, was able to draw on a level 244 t., would in no circumstance, even on the excellent Holyhead road, be able at the same pressure to draw more than ⅛ of that load, or 30 t.

Thus its *maximum* load on a common road would only be the ⅖ of its *minimum* load on the railway.

To which must still be added, that the resistance of the engine in the case of its progress on a common road, will be, like the resistance of the wagons, considerably augmented. It will therefore be obliged, in order to move itself, to consume a much greater portion of its own power, which will diminish in the same proportion the 30 t. it might else have drawn.

We see that on a common road, the resistance of the carriages puts much quicker a stop to the useful effect than the adhe-

* Report of the Holyhead Road Commissioners.

sion does on a railway; and that, under all circumstances, the advantage in regard to the load is in favor of the engines on railways.

But there is another consideration that appears to militate in favor of what is called steam-carriages, that is to say, locomotive engines employed on common roads; that consideration is the expense of constructing a railway which is thus avoided. A considerable economy is expected to be made by that means. The construction and keeping in repair of the railway, is in fact a very heavy expense. The capital laid out for that will be entirely avoided. But, at the same time, the chief advantage of the undertaking will be lost.

Why demur to lay out capital, if a considerable profit is to be derived from it? Why save the first expense, if the consequence is the necessity of spending more annually than the interest of the capital saved?

This is exactly the present case. The construction of a railway is undoubtedly expensive; but it is the principal element of success. It is money employed to level the road, in order not to have any difficulty afterwards in conveying the goods, and to begin from that moment to reap the profits. What would be said to a man who should propose to cross the fields, in order to avoid the constructing of roads? The answer would be, that the loss in freight would be greater than the expense of construction.

The same is true in regard to railways. If there be an advantage in constructing them for horses, as an experience of sixty years' prosperity has sufficiently demonstrated, how is it possible that there should be none for the use of locomotive engines or any other moter? Whatever advantage those engines may offer on common roads, they must necessarily present a much greater one on railways.

It may appear surprising to see a steam-engine on a common road draw two or three stage coaches with 12 or 15 passengers in each. But the Liverpool engines at the time of the races have drawn as much as 800 persons in a single train, at a speed of 15 miles an hour.

It will perhaps be said that steam-carriages are able to draw more than three stage-coaches. As yet, however, none have been found that have done more. The greatest part of them do not even carry more than 18 or 20 passengers. It is easy to see the cause that puts so soon a limit to their load. There exists no common road without considerable acclivities. As they must be overcome, it is necessary to give to the engine only the load which it can take over the steepest of those ascents. Now, on an acclivity of $\frac{1}{12}$, the weight of three stage-coaches, or 9 t., increased by the weight of the engine, presents, on account of the gravity, a resistance equal to that which 45 t. or 15 stage-coaches would offer on a level. A steam-engine that is to draw three stage-coaches during a journey of some length, must therefore be able to draw 15 loaded stage-coaches on a level common road. This is

all that can be supposed, even admitting improvements, for that force corresponds with 120 stage-coaches on a railway. We must take therefore two or three stage-coaches at most, as the regular load of these engines.

But the levelling, which is the result of the expense attending the construction of a railway, renders those same engines capable of drawing 40 loaded stage-coaches or wagons. This is thus 12 or even 20 times as much. To do the same work on a common road, 12 times as many engines will consequently be required at once, with 12 times as many engine-men and fire-men. Considering also the disadvantage there is for the engines, in respect to fuel, in drawing small loads, we may confidently calculate that the expense for fuel will be doubled. Of this we will be the more convinced, if we take into account the surplus of power necessary to move the engine itself on a road full of asperities.

Besides the repairs of the engines are, even on railways, a considerable expense. At Liverpool, of the 30 engines belonging to the company, ten only are in *activity* on the line for the conveyance of goods and passengers. The effective work is eight or ten hours a day, and the expense for maintaining in activity those ten engines, amounts to more than £18,000, or £1,800 a year for each of them. These expenses are paid and become a source of profit, because on a railway the engines draw considerable trains; but it would not be the same thing if the trains were reduced, or, in other words, if a greater number of engines were required to do the same work. Moreover, if the engines, instead of sliding without jolts on the smooth surface of a railway, were obliged to run on the rough soil of our roads, how great would not be the expense of repairs. And we have 12 times as many engines to repair.

Outlay and interest of capital for engines, salary of engine-men and assistants, fuel, repairs, all these articles will soon have absorbed the expected economy.

Besides, the chief advantage of such undertakings, consists in the speed with which the haulage is executed. When the 29½ miles between Liverpool and Manchester were travelled in four hours, there were about 450 passengers going daily from one of those towns to the other. At present when, thanks to locomotive engines, the journey is completed in an hour or an hour and a half, there are 1,200 passengers a day. The speed has the greatest share in the creation of that profit. It must be given up if the engines are only to run eight or ten miles an hour.

Now, the 8 or 9 t. that the locomotive engines weigh on railways, allow us to give them a sufficient extent of boiler to generate a certain quantity of steam per minute, and consequently a certain speed. If the nature of the road obliges us to reduce the weight of the engine to 3 t. only, with the necessity of making all its different parts stronger, on account of the jolts on a rough surface, there will naturally be less heating surface in the boiler, and consequently less possible speed. And, in

fact, the steam coaches scarcely do more than eight or ten miles an hour.

As a last reflection we shall add, that until the present moment the success of locomotive engines on common roads, continues, as a speculation, to be very uncertain, whilst the prosperity of railways, whatever be the moving power, is demonstrated by their continued extension. Steam-coaches may be improved, but, we repeat, whatever be the advantages they may offer on a common road, it is not to be contested that, by employing them on a railway, those advantages will be infinitely greater.

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## CHAPTER IX.

### OF THE FUEL.

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**§ 1. Of the Consumption of Fuel in Proportion with the Load.**

We have still an important article to discuss. That is the fuel.

From what we have said above, the steam generated in the boiler at whatever pressure it may be, takes, in passing into the cylinder, a pressure exactly determined by the resistance on the piston. The mode of action of the engine, is thus limited to the transformation of a certain quantity of steam, drawn from the boiler, and consequently at the pressure of the boiler, into steam at a lower pressure and of a proportionally greater volume.

Let us suppose the same engine, with the same pressure in the boiler, and travelling the same distance with two different loads. The distance travelled being the same, the number of turns of the wheel, and consequently of strokes of the piston or cylinders of steam expended during the journey, will be the same in the two cases. If the load had been the same, there would also have been identity in the nature of the steam expended. But as the loads differed, the same number of cylinders will indeed have been expended, but the degree of the steam in the cylinders will be different in the two cases.

Then the expense of moving power will be in one case a certain volume of steam at the pressure R, for instance, and in the other case the same volume at the pressure R'.

The pressure of the steam in the boiler being supposed the same in the two experiments, its temperature will also be the same. As the temperature experiences no reduction during its passage to the cylinders, the pipes and the cylinders themselves being immersed in the boiler, or surrounded by the flame of the fire-place, the temperature of the steam in the cylinders will be the same in the two cases.

Thus the volume and temperature of the steam expended during the journey will be the same in both circumstances. The pressure of the steam in the cylinder will alone have undergone a change. Consequently the mass or weight of steam expended, will be in each case in the ratio of the pressure in the cylinder.

The weight of the steam being equal to that of the water that generated it, the weights of water evaporated will then be to each other as the pressures in the cylinder, or, in other words, as the resistances on the piston. Besides as the water is first transformed into steam at the pressure of the boiler, that is to say, in both cases into steam at the same degree of pressure, it follows also that the quantities of fuel necessary for the evaporation, will be to each other as the pressures or total resistances on the piston.

This shows that the consumption of fuel is independent of the speed, and that it depends only on the resistance on the piston.

If in the two journeys we consider, the pressure happens not to be identically the same in the boiler, there will be a little more fuel consumed in that case where the pressure has been the greatest, because the pressure could only increase in consequence of an increase of temperature. But as degrees of pressure very distant from each other are produced by very similar temperatures, the difference of consumption occasioned by that circumstance will be of little importance, and will not be perceived in practice.

This principle gives the proportions of the consumption of fuel for the same engine with different loads, and may thus serve to determine its consumption in all circumstances, as soon as it is known in one determined case.

If for instance Q and Q' are the quantities of fuel expended with two given loads, the resistance on the piston with the first of these loads being expressed by R, and with the second by R', we shall have

$$\frac{Q}{Q'} = \frac{R}{R'}.$$

But we have already calculated the resistance R on the piston of an engine. We have seen (Chap. V. Art. II.) that M being the load expressed in tons, tender included; F the friction of the engine without load; d the diameter of the cylinder; D the diameter of the wheel; l the length of the stroke; ρ being the atmospheric pressure per unit of surface, n the resistance of the load per ton, and δ the additional friction of the engine per ton of load, that resistance is

$$R = [F + (\delta + n)\,M]\,\frac{D}{d^2 l} \times \rho.$$

Thus, for a different load drawn by the same engine, we shall have

$$R' = [F + (\delta + n)\,M']\,\frac{D}{d^2 l} + \rho\,;$$

consequently,

$$\frac{Q}{Q'} = \frac{[F + (\delta + n)\,M']\,\dfrac{D}{d^2 l} + \rho}{[F + (\delta + n)\,M']\,\dfrac{D}{d^2 l} + \rho}.$$

This equation can be written in the following form:

$$\frac{Q}{Q'} = \frac{M + \left[\dfrac{\rho\,d^2 l}{(\delta + n)\,D} + \dfrac{F}{\delta + n}\right]}{M' + \left[\dfrac{\delta\,d^2 l}{(\delta + n)\,D} + \dfrac{F}{\delta + n}\right]}.$$

So that the expression

$$\left\{\frac{\rho\,d^2 l}{(\delta + n)\,D} + \frac{F}{\rho + n}\right\}$$

being calculated once for all the given dimensions of the engine, nothing more will be necessary than to add that quantity to M and M', in order to have the required proportion of Q to Q'.

Let us suppose, for instance, that we have an engine similar to the 11-inch cylinder engine of Liverpool, viz. :

F, friction of the engine without load - - - = 110 lbs.
d, diameter of the cylinder 11 in., or in feet - - - = 0.917 ft.
D, diameter of the wheel = 5 ft.
l, length of the stroke 16 in., or in feet - - - = 1.33 ft.

As besides we have

ρ, atmospheric pressure per square foot - - - = 23.117 lbs.
n, resistance of the load per ton - - - - - = 8 lbs.
δ, additional friction of the engine per ton of load = 1 lb.

For this case we shall have

$$\frac{\rho\,d^2 l}{(\delta + n)\,D} + \frac{F}{\delta + n} = 65.$$

In the case of a 12-inch cylinder engine, with 152 lbs. friction, like the ATLAS, the value of this quantity would be 80.

And, finally, for the VESTA, with 11½ inch cylinders and 187 lbs. friction, the same quantity is 75.

Thus, in the case of those different sorts of engines, we shall have for the quantity of fuel expended with two different loads M and M',

$$\frac{Q}{Q'} = \frac{M + 65}{M' + 65},$$

or

$$\frac{Q}{Q'} = \frac{M + 80}{M' + 80}.$$

or finally

$$\frac{Q}{Q'} = \frac{M + 75}{M' + 75}.$$

In these expressions M stands for the load, tender included; the weight of the tender is meant, therefore, to be added to the load, if it was not included in it from the first.

We easily perceive that the quantity $\frac{F}{\delta + n} + \frac{\rho\,d^2 l}{(\delta + n)\,D}$ is nothing but the friction of the engine and the atmospheric pressure referred to the velocity of the engine, and represented by the number of tons that would offer an equivalent resistance. Thus the number M of tons, added to that quantity represents the total resistance overcome by the engine. Consequently the principle established above amounts to this : that the power applied is in proportion to the *total* resistance to be overcome, as was naturally to be expected.

This invariable quantity, which must be added to the load, expresses, as we have said, the aggregate inert resistance of the engine, or, if we may be permitted to use that expression, the *constant vis inertiæ* of the engine. As this quantity differs for each engine, and as it must be calculated separately for each of them, we shall join here a table which will show its value, superseding thus the necessity of calculating it, for the engines most commonly used on railways.

A TABLE OF THE CONSTANT VIS INERTIÆ OF THE ENGINES, NECESSARY TO DETERMINE THE CONSUMPTION OF FUEL WITH DIFFERENT LOADS.

| Designation of the Engine. | Constant vis inertiæ, expressed in tons. |
|---|---|
| Engine with cylinders 11 in., or in feet . . 0.917 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 120 lbs. | 66 t. |
| Engine with cylinders 12 in., or . . . . 1 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 150 lbs. | 80 t. |
| Engine with cylinders 13 in., or . . . . 1.083 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 165 lbs. | 92 t. |
| Engine with cylinders 14 in. or . . . . 1.166 ft. stroke 16 in., or 1.33 ft. wheel . . . 5 ft. friction . . . 180 lbs. | 105 t. |
| Engine with cylinders 12 in., or . . . . 1 ft. stroke 18 in., or 1.50 ft. wheel . . . 5 ft. friction . . . 165 lbs. | 107 t. |

## § 2. Experiments on the Quantity of Fuel consumed by the Engines.

The above formula, which is of easy application, gives the absolute quantity of fuel required by an engine in all circumstances, provided the consumption of the engine in a given case be known.

The only thing necessary, will therefore be, to make one experiment on the fuel consumed by the engine with a given load, which will be the data of the problem.

Evidently between two different engines, this first data will differ according to the particular construction of each engine, and chiefly according to the extent of heating surface of its boiler. The following experiments were therefore undertaken on the Liverpool and Manchester Railway, in order to obtain a knowledge of this data, and likewise to verify the theoretical principle exposed above.

In these experiments the tender was first carefully emptied, then the coke was accurately weighed and put into the tender. The fire-place of the engine was besides filled with fuel, up to the lower part of the door. At the end of the experiment, the fire-place was again filled to the same height, and the coke remaining in the ten-

der was weighed with the same care as at setting off.

As an engine that ascends alone, with its train, an inclined plane exerts necessarily a greater effort than if at that moment it were helped by an additional engine, we have put down whether the engine was helped or not in going up the plane. We have also inscribed the state of the weather and the temperature of the water in the tender, in order that those circumstances might be taken into consideration.

In these experiments, the co-operation of the persons attached to the establishment was often necessary. We must particularly mention Mr. J. Dizon, the resident engineer, to whom we are indebted also for his accurate levelling of the road, and many other pieces of information obligingly communicated to us.

### EXPERIMENTS ON THE QUANTITY OF FUEL CONSUMED BY THE LOCOMOTIVE ENGINES, WITH GIVEN LOADS.

| Name of the Engine. | Date of the experiment. 1834. | Nature and Weight of the load, not including the tender. | tons. | Time of the trip of 29½ miles. h. m. | Delays on the road, not included in the above time. m. | Average effective pressure, in lbs. per square inch. lbs. | Coke of prime quality consumed during the journey. lbs. | Coke per ton per m'le on a level, help deducted on incl. plane. lbs. | Help on the inclined plane. | Temperature of the water in the boiler. | State of the weather. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ATLAS, from L. to M. | 23 July | 40 wagons | 190.00 | 3. 2 | 15 | 53.7 | 1596 | 0.28 | Help. | Cold in the tender. | Calm. |
| Do. | 9 July | 25 do. | 123.13 | 1.48 | 12 | 53 | 1102 | 0.34 | Help. | Lukewarm in the tender. | " |
| Do. | 4 Aug | 25 do. | 122.64 | 1.58 | 0 | 53 | 1224 | 0.34 | Help. | Cold in the tender. | " Fair and calm. |
| | | | | | | | | | | *The connecting rods of the wheels too tight.* | |
| Do. | 14 July | 25 do. | 118.90 | 1.31 | 19 | 61.5 | 1118 | 0.32 | Help. | Cold in the tender. | Fair and calm. |
| Do. | 11 July | 25 do. | 117.61 | 1.41 | 5 | 53 | 1136 | 0.33 | Help. | Lukewarm in the tender. | " |
| Do. | 28 June | 25 do. | 113.90 | 1.50 | 5 | 53 | 1104 | 0.33 | Help. | One piston too slack. Rather hot in the tender. | Calm. |
| Do. | 16 July | 20 do. | 94.66 | 1.25 | 23 | 53.5 | 1081 | 0.39 | Help. | Little lukewarm in tender. | Fair and calm. |
| Do. | 17 July | 15 do. | 65.40 | 1.27 | 3 | 54 | 1012 | 0.52 | Help. | Very hot in the tender. | " |
| | | | | | | | | | | *The axle-box of one of the wagons too tight.* | |
| Do. from M. to L. | 31 July | 8 loaded wagons and 4 empty | 35.15 | 1.54 | 0 | 30 | 881 | 0.73 | No help. | | " |
| Do. | 17 July | 3 loaded wagons and 8 empty, and 2 wagons on a part of the road. | 25.30 | 1.26 | 3 | 54.5 | 720 | 0.82 | No help. | Very hot in the tender. | Fair and calm |
| VESTA, from L. to M. | 5 July | 20 wagons | 92.75 | 1.42 | 5 | 53 | 916 | 0.33 | Help. | Hot in the tender. | Calm. |
| Do. from M. to L. | 1 Aug | 5 loaded wagons and 5 empty | 26.15 | 1. 5 | 0 | 51 | 774 | 0.80 | No help. | Very hot in the tender. | Fair, moderate [wind in favor of the motion. |

*Engine a little stiff. It comes out of the repair-yard.*

## EXPERIMENTS ON THE QUANTITY OF FUEL CONSUMED BY THE LOCOMOTIVE ENGINES, WITH GIVEN LOADS.

| Name of the Engine. | Date of the experiment. | Nature and Weight of the load, not including the tender. | Time of the trip of 29½ miles. | Delays on the road not included in the above time. | Average effective pressure, in lbs. per square inch. | Coke of prime quality consumed during the journey. | Coke per ton per mile on a level, help deduced on incl. plane. | State of the weather. | Help on the inclined plane. | Temperature of the water in the boiler. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1834. | tons. | h. m. | m. | lbs. | lbs. | lbs. | | | |
| VULCAN, from L. to M. | 1 July | 20 wagons . . 97.70 | 3.37 | 3 | 54.5 | 1071 | 0.37 | Calm. | Help. | Lukewarm in the tender. |
| Do. from M. to L. | 22 July | 9 1st cl. carriages 34.97 | 1.17 | 3 | 54.5 | 664 | 0.56 | Fair, very light wind against the motion. | Nohelp. | Cold in the tender. |
| LEEDS, from L. to M. | 15 Aug | 20 wagons . . 83.44 | 1.35 | 0 | 54 | 897 | 0.36 | Fair and calm. | Help. | Rather lukewarm in tender. |
| Do. from M. to L. | 15 Aug | 8 do of which 1 at half way } 32.01 | 1.17½ | 3 | 49 | 690 | 0.62 | Fair and calm. | No help. | Very hot in the tender. |
| FURY, from L. to M. | 24 July | 10 do . . . 51.16 | 1.30 | 0 | 60 | 806 | 0.46 | Fair and calm. | Nohelp. | Cold in the tender. |
| Do. from M. to L. | 24 July | 10 do . . . 63.80 | 1.35 | 0 | 59 | 746 | 0.49 | Fair, side wind tolerably strong by intervals. | Nohelp. | Cold in the tender. |
| JUPITER, from L. to M. | 16 July | 8 1st cl. carriages 33.05 | 1.12 | 3 | 53 | 742 | 0.76 | Fair and calm. | Help. | Almost cold in the tender. |
| Do. from M. to L. | 16 July | 7 do | 30.09 | 1.12 | 4 | 53 | 836 | 0.94 | Fair, moderate wind contrary to the motion. | Help. | " |
| FIREFLY, from L. to M. | 26 July | 8 do | 36.40 | 1.35 | 5 | 44 | 879 | 0.82 | Almost cold in the tender. Fair. | Help. | The engine is not in a good condition. |
| Do. from M. to L. | 26 July | 8 do | 36.40 | 1.18 | 5 | 49 | 870 | 0.81 | Rainy, wind tolerably strong against motion. | Help. | The engine is not in a good condition. |
| | | Sum - - 1605.65 | " | " | " | 20865 | " | | | |

*Accessory Circumstances.*

In examining these experiments, we find that neither the pressure in the boiler, nor the velocity of the motion, have any remarkable influence on the result. This fact was already indicated by theory.

We also remark the advantage that is found in respect to fuel, in making the engines, whenever it is possible, draw the greatest loads their power will permit. For instance, the ATLAS, drawing a load of 25 t., consumed 720 lbs. coke, whereas, in drawing 190 t., or a load eight time as great, it only consumed double the quantity of coke. This difference must evidently, as we have explained above, be attributed to the expense of power necessary in each case, in order to overcome the resistance the coke employed was of prime quality, or *Worsley coke*, which is prepared on purpose for iron-founderies. When gas-coke is used the engines consume about 12 per cent. more without reckoning the loss resulting from the friability of that combustible. It has moreover been ascertained, that the sulphurous parts it contains are highly destructive of metals. For that reason its use has been completely given up on the Liverpool Railway, notwithstanding its low price.

In making use of coals of good quality, the quantity required is nearly the same as that of good coke; but this combustible has in regard to the preservation of the engines, the same defects as gas-coke.

of the atmosphere, the engine, and its tender.

We must add, that in those experiments Respecting the distance travelled by the engines in these experiments, the railway from Liverpool to Manchester is generally reckoned 30 miles long, and considered a level; but as a greater degree of accuracy is required in the calculation, and as we wish to deduce from these experiments the really corresponding consumption of coke on a level railway, we must reckon as follows.

One part of the line travelled by the locomotive engines is 29½ miles long. If we divide it in three parts, we see that 1 t. drawn from one end of the railway to the other, opposes the following resistances. (See the section of the railway, Chap. V. Art. VII. § 1.)

$$\begin{array}{ll} & \text{ton. miles.} \\ \text{1 t. at } 26\tfrac{1}{2} \text{ miles, on nearly a level} & 1 \text{ at } 26\tfrac{1}{2} \\ \text{1 t. at } 1\tfrac{1}{2} \text{ mile, ascending } \tfrac{1}{96} \\ \text{or } \tfrac{1}{89}, \text{ equal (friction and} \\ \text{gravity) to 4 t. drawn to} \\ \text{the same distance on a level,} \\ \text{or 1 t. at 6 miles} & 1 \text{ at } 6 \\ \text{1 t. at } 1\tfrac{1}{2} \text{ mile, descending by} \\ \text{the sole force of the gravity} & 0 \quad 0 \\ \hline \text{Sum} & 1 \text{ at } 32.5 \end{array}$$

Thus when the engines ascend the plane without help, the work they actually do is equal to the traction of a similar load to a distance of 32.5 miles on a level.

If they ascend the plane with the help of one or more other engines, their share of the load in ascending is on an average only ⅓ of the whole on the plane, and thus the work they do is equal to the traction of their load to $26.5 \times 2 = 28.5$ miles.

This does not include the surplus of resistance owing to the gravity of the engine and its tender in going up the plane. Their average weight being together from 13 to 14 t., the gravity of which on the plane is equal to the resistance of about 40 t. on a level, we see that this fresh effort required of the engine, equals the traction of 40 t. to a mile and a half, which is the length of the acclivity. If, therefore, the train itself weighs 30 t. without the tender, as is the case with engines that are not helped by additional ones, the work is equal to the traction of that train two miles more than the length of the line. If, on the contrary, the load weighs 60 or 80 t., as is in general the case with engines that are helped on the inclined planes, the additional traction of 40 t. for 1½ mile, is equal to the traction of the whole load to a mile.

Then for trains that receive no help at the passage of the inclined planes, we must reckon the distance for which the draft has taken place, as equal to 34½ miles *on a level;* and for the engines that are helped on the acclivity, we must reckon the work they have done as equal to the traction of their load to a distance of 29½ miles *on a level.* The difference which exists in these two cases, is of ⅓ in plus for the unassisted engines. This is the work done by the helping engines, when they

are employed, and the surplus of work produced by the passage of the planes.

It is from those distances of 29.5 miles and 34.5 miles, that the numbers placed in the eighth column of the preceding table have been deduced in each experiment.

In examining the results contained in that table, we find that they agree with the rule deduced above from the theory of the engine.

For the ATLAS, the average of the experiments made with 25 wagons, gives 119 t. conveyed by 1136 lbs. of coke. Calculating upon this data, and adding $\frac{1}{6}$ for the cases where there has been no help, we find

| | tons. | lbs. | Calcula- | Experi- |
|---|---|---|---|---|
| | | | tion. | ment. |
| ATLAS | 119 and tender 1136. | | | |
| | 190 and tender | | 1531 | 1596 |
| | 95 and tender | | 1002 | 1081 |
| | 65 and tender | | 835 | 10 12 |
| | 35 and tender | | 779 | 881 |
| | 25 and tender | | 719 | 720 |
| VESTA | 93 and tender 916. | | | |
| | 34 and tender | | 668 | 774 |
| VULCAN | 98 and tender 1071. | | | |
| | 34 and tender | | 773 | 664 |
| LEEDS | 83 and tender 897 | | | |
| | 32 and tender | | 697 | 690 |
| FURY | 51 and tender 806. | | | |
| | 44 and tender | | 759 | 746 |

If we take into account the accessory circumstances, we shall find between the calculation and the experiment, as complete a coincidence as the nature of the experiments themselves could allow; for, besides the above-mentioned circumstances, the greasing of the carriages, the quality of the coke, and, above all, the manner in which the fire-place is filled after the experiment, are subject to produce considerable differences, notwithstanding the most scrupulous attention.

The experiments we have related, give the quantity of coke consumed during the trip.

It is however clear, that in the interval between one trip and another, the engine, although at rest, continues to consume a certain quantity of fuel, because its fire must be kept up for the following journey. It is true, that several of those engines, such as the ATLAS, VESTA, and some others, have a particular sort of apparatus, by means of which, while the engine is at rest, the steam that continues to be generated in the boiler may be led to the tender. That steam is then not completely lost, being condensed in the boiler, and serving to heat the water it contains. But all the engines are not disposed in that manner.

Besides, there is in all cases consumed, every morning, a certain quantity of fuel for heating all the parts of the engine and the water of the boiler.

A surplus of consumption must therefore be calculated for those two objects. This is a practical piece of information which will find its place hereafter.

The researches contained in the work, give the solution of all such questions as are most important for the application of locomotive engines to the draft of loads on railways. They give the means of measuring the pressure of the steam; of calculating the load, the velocity, and the proportions of the engines; of valuing the different sorts of resistance they have to overcome; of taking into account the influence of additional circumstances on their motion; and, finally, of knowing their consumption of fuel.

Here naturally our work terminates. However, as a knowledge of these engines cannot be complete, unless we are able to calculate also the expenses they will require for a given draft, we add in an Appendix the necessary information, by means of which that important point may be established.

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THE POTATO SQUASH.—We have received some *Squash Seeds*, together with the following note.

MR. FESSENDEN,

Sir—I send you for distribution, though perhaps, rather late a few squash seeds, which I obtained in Illinois last season. They are known there by the name of the "Potato Squash," resembling very much the sweet potato, being very dry and sweet to the taste. If they can be raised here as well as there, they will surpass all others. I ate of them mashed as we mash our common potato, and their flavor was exceedingly fine. They grow about the size of the common short necked squash, and weigh about six pounds; their color nearly white.

Respectfully,
JACOB N. BANG.

We are much obliged to the donor of the above mentioned seeds, and will distribute them among careful cultivators, in small parcels for the benefit of the commonweal. [New-England Farmer.]

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### MILL–DAM FOUNDRY.

WILL be sold at public auction, (unless previously disposed of at private sale,) the above well known establishment, situated one mile from Boston. The improvements consist of—

No. 1. Boiler House, 50 feet by 30 feet, containing all the necessary machinery for making boilers for Locomotive and other steam Engines.

No. 2. Blacksmith's Shop, 50 feet by 20, fitted with cranes for heavy work.

No. 3. Locomotive House, 54 feet by 25, used for putting together Locomotive Engines. Several of the best Engines in use in the United States have been put in this establishment.

No. 4. A three story brick building, covered with slate, 120 feet by 46, containing two water-wheels, equal to 40 horse power; Machine Shop, filled with lathes, &c.; Pattern Shop; Rolling Mill and Furnaces, capable of rolling 4 tons of iron per diem, exclusive of other work; three Trip Hammers, one of which is very large; engine for blowing Cupola Furnaces, moved by waterwheel; one very superior 12 horse Steam Engine, which could be dispensed with; and a variety of other machinery.

No. 5. An Iron Foundry, 80 feet by 45, with a superior air Furnace, and two Cupolas, Core oven, Cranes, &c. fitted for the largest work. Attached to the Foundry is a large ware-house, containing Patterns for the Castings of Hydraulic Presses, Locomotive and other Steam Engines, Lead Mill Rolls, Geering, Shafts, Stoves, Grates, &c. These were made of the most durable materials, under the direction of a very scientific and practical Engineer, and are supposed to be of great value.

No. 6. A building, 65 feet by 36, containing a large stack of chimneys, and furnaces, for making Cast Steel. This building is at present used as a boarding-house, and can accommodate a large number of men.

No. 7. A range of buildings, 200 feet long by 36, containing counting room, several store rooms, a Brass Foundry, room for cleaning castings, a large loft for storing patterns, stable for two horses, &c. &c.

The above establishment being on tide water, presents greater advantages for some kinds of business than any other in the United States. Coal and Iron can be carried from vessels in the harbors of Boston, to the wharf in front of the Factory, at 25 to 30 cents per ton. Some of the largest jobs of iron work have been completed at this establishment; among others, the great chain and lift pumps for freeing the Dry Dock at the Navy Yard, Charleston.

The situation for Railroad work is excellent, being in the angle formed by the crossing of the Providence and Worcester Railroads. The Locomotive "Yankee," now running on the latter road, and the "Jonathan," purchased by the State of Pennsylvania, were built at these works. With the Patterns and Machinery now n the premises, 12 Locomotives, and as many tenders, besides a great quantity of cars and wagons, could be made per annum.

For terms, apply to
THOS. J. ECKLEY, Treas. &c. Boston, or to ROBERT RALSTON, Jr. Phila.
Boston, April 21, 1835.　　j25—4t

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